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Effect of long-term nutrient management on potassium dynamics in calcareous (*Vertic haplustepts*) soil

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Abstract
A field experiment was conducted at instructional Farm, Junagadh Agricultural University, Junagadh to bring about the effect of long-term nutrient management on potassium dynamics in calcareous (*Vertic Haplustepts)* soil**.** An experiment was comprised with twelve treatments in RBD design with three replication. The result revealed that the application of FYM maintained or increased potassium status of LTFE soils. In treatments of FYM (T_8 and T_9), the status of potassium fractions increased. There was overall decrease in available-K_2O status of LTFE soils after 18 year, except in treatments which received FYM (T_8 and T_9), where K_2O status of soil increased as compared to initial status. Water soluble-K also decreased in LTFE soil after a span of 18 years, except in treatments which received FYM (T_8 and T_9). Same results were also recorded in case of exchangeable-K, HNO_3 soluble-K, reserve-K and total-K, here also approved that for maintaining K fertility of soil at long run, it is essential to add organic fertilizer with inorganic ones for maintaining available potassium level in soil, application of organic manure is essential. In fact, all fractions of potassium decreased after a long run in intensive cropping of LTFE soils without addition of FYM. So it is alarming us to use organic fertilizer with inorganic one for maintaining K fertility status of soil in long run. At initial stage of experiment (1st year) available-K_2O status of LTFE soils showed high category (> 280 kg K_2O ha^{-1}), but after long run (18 year) it decreased to medium category (140-280 kg K_2O ha^{-1}), except in treatment of FYM application (T_8 and T_9), where increment in K_2O level was found rather than its depletion. Further it was established that, FYM is essential for maintaining soil fertility at long run. Similar results were also recorded in case of all other fractions of potassium.

Keywords: Potassium fractions, LTFE (Long term fertilizer experiment)

Introduction
Potassium (K) is absorbed by plants in larger amounts than any other nutrient except N. Although total soil content exceeds crop uptake during a growing season, in most cases only a small fraction of it available to plants. Total soil K content ranges between 0.5 to 2.5% and it is lower in coarse-textured soils formed from sandstone or quartzite and higher in fine textured soils formed from rocks high in K-bearing minerals. The potassium is mobile in plant, unlike other major elements, it's not the integral part of the plant component but, it acts as a catalyst for carbohydrate and nitrogen metabolism, protein synthesis as well as formation, break down and translocation of starch. It also regulates the activity of other essential elements in plant. It neutralizes physiologically important organic acid and activates various enzymes promoting the growth of meristematic tissues. It also plays an important role in monitoring the water balance in plants. After introduction of high yielding varieties and intensive and multiple cropping system along with use of high analysis nitrogenous and phosphatic fertilizers on long run resulting now the soils are started depleting in potassium from high to medium and up to low levels as evidenced by soil testing and crop response (Prasad, 1992) [9]. In such conditions crop may respond to potassium application. Therefore, there is a need to study the dynamics of different forms of potassium in intensive agriculture on long run basis, present investigation was carried out.

Materials and Methods
The long-term fertilizer experiment was started in the year 1999 at the Instructional Farm, College of Agriculture, Junagadh Agricultural University at Junagadh to know effect of continuous application of fertilizers (N, P, K) and manure in a crop rotation of groundnut-

wheat cropping sequence. Surface soil samples (0-15 cm) were collected from the experimental soils conducted on groundnut-wheat sequence in RBD during the year 1999 (Initial), 2004-05 (6^{th} year, after wheat), 2010-11 (12^{th} year, after wheat) and 2016-17 (18^{th} year). The treatments were T_1- 50 % NPK of recommended doses in Groundnut-Wheat sequence, T_2- 100 % NPK of recommended doses in Groundnut -Wheat sequence, T_3 -150 % NPK of recommended doses in Groundnut -Wheat sequence, T_4 - 100 % NPK of recommended doses in Groundnut -Wheat sequence + $ZnSO_4$ @ 50 kg ha^{-1} once in three year to Groundnut only (i.e. '99, 02, 05, … etc), T_5 - NPK as per soil test, T_6 - 100 % NP of recommended doses in Groundnut - Wheat sequence, T_7 - 100 % N of recommended doses in Groundnut -Wheat sequence, T_8 - 50 % NPK of recommended doses + FYM @ 10 t ha^{-1} to Groundnut and 100 % NPK to Wheat, T_9 - Only FYM @ 10 t ha^{-1} to Groundnut and @ 15 t ha^{-1} to Wheat., T_{10} - 50 % NPK of recommended doses in Groundnut -Wheat sequence + Rhizobium + PSM to Groundnut and 100 % NPK to Wheat, T_{11} - 100 % NPK of recommended doses in Groundnut - Wheat sequence (P as SSP) and T_{12} – Control. These soil samples, after air-drying, were ground with wooden mortar and pestle to pass through a 2 mm plastic sieve. The bulk soil samples were stored in polyethylene bags for chemical analysis. These soil samples were analyzed to determine the different forms of potassium on the basis of below mention method.

Water soluble potassium

Water soluble potassium was extracted from 1:2 soil: water ratio, after shaking in a mechanical shaker for two hours and then allowing it to stand for a period of sixteen hours as per the procedure described by Mc Lean's (1960).

Available potassium

A five gram soil sample was shaken with neutral normal ammonium acetate (25 ml) and extracted as per the method suggested by Hanway and Heidal (1952) [4] and potassium was determined from the extract by a flame photometer (Jackson, 1973) [5].

Nitric acid soluble potassium (1N HNO_3 soluble K)

This was extracted from soil with 1 N HNO_3 in the ratio 1:10 (Soil:HNO_3) and boiled for 10 minutes as per the procedure described by Wood and DeTurk (1941) [16].

Exchangeable potassium

It was calculated by deducting the values of water- soluble potassium from those of available potassium.

Reserve potassium

It was calculated by deducting the values of available potassium from those of nitric acid soluble potassium.

Total potassium

It was estimated as per the method suggested by Pratt (1951) [10]. 0.1 gm soil was digested in 5 ml hydrofluoric acid and 0.5 ml perchloric acid in a platinum crucible. After cooling, 5 ml of (6 N) HCl and 5 ml of water were added and then boiled gently. When residue had completely dissolved in hydrochloric acid, it was transferred into 100 ml volumetric flask and volume was made at the mark and stoppered and shaken by up and down.

Depletion per cent

These nutrients depleted from soil by different cycles were calculated by the formula:

$$\text{Depletion of nutrient (\%)} = \frac{\text{Nutrient status of index year} - \text{Nutrient status of final year}}{\text{Nutrient status of index year}} \times 100$$

Results and Discussion

The results obtained from the present investigation as well as relevant discussion have been presented under following heads:

Available K_2O

Initial status of K_2O in LTFE soils was almost same, but it was affected significantly and found significant differences due to various treatments after 6^{th}, 12^{th} year, 18^{th} year and when pooled over years. The value of Available K_2O (kg ha^{-1}) recorded highest value in treatment No. 9 (FYM @ 10 t ha^{-1} to groundnut and @ 15 t ha^{-1} to wheat) in 6^{th}, 12^{th} year, 18^{th} year and when pooled over years i.e. 892, 363, 429 and 520 kg ha^{-1}, respectively. There was marginal overall decrease in soil status of Available K_2O after a span of 12 years. Rajani *et al.*, (2010) [11] found similar result and stated that the potassium availability however decreased over initial level in all treatments except in those which received FYM. Majumdar *et al*. (2002) [7] also observed similar trend that application of FYM significantly increased water soluble, exchangeable, available and non-exchangeable K in soil. The Y x T interaction was significant.

Water soluble K

Water soluble K status of LTFE soil at initial stage was somewhat different in all plots. After 6^{th}, 12^{th}, 18^{th} and when pooled over years it also affected significantly by treatments. In next year's (6^{th}, 12^{th}, & 18^{th} year) and pooled it was found significantly highest in plot which received FYM @ 10 t ha^{-1} to groundnut and @ 15 t ha^{-1} to wheat (T_9), which was at par with T_8 (50% NPK + 10 t FYM ha^{-1} to groundnut and 100% NPK to wheat. It have been due to transformation of reserve K to water soluble K a dissolving effect of organic acid which was extract of FYM. The Y x T interaction also showed significant differences. Overall content of Water soluble K was marginally decreased after a period of 18 years. This result ascribed to that 72 per cent of W.S.-K was decreased due to intensive cropping of groundnut-wheat sequence in medium black calcareous soils (Venugopal *et al.,* 2016) [15].

Exchangeable K

The significantly highest values of Exchangeable K were recorded due to application of FYM @ 10 t ha^{-1} to groundnut and @ 15 t ha^{-1} to wheat (T_9) after 6^{th}, 12^{th}, 18^{th}year of experiment and when pooled over years, i.e.688, 282, 339& 405, respectively. All plots of LTFE experiment exhibited overall same Exchangeable K value at initial stage of experiment. The Y x T interaction was significant. The overall Exchangeable K status marginally decreased after 12 years. This result was in agreement with finding of Das *et al.*(2000) [2] who stated that 78 per cent of Exchangeable K was decreased due to intensive cropping of groundnut- wheat sequence in medium black calcareous soils. Santhy *et al.,* (1998) [12] also observed similar trend that Exchangeable K was negatively balanced due to continuous cropping with a decrease of 43 per cent from the initial level.

HNO_3 soluble K

The data presented in showed that nitric acid soluble K status was significantly different in various plots at initial, after 6th year, 12th year, 18th year& when pooled over years. Here also, application of FYM @ 10 t ha^{-1} to groundnut and @ 15 t ha^{-1} to wheat (T_9) increased significantly the content of HNO_3 soluble K in soil. The Y x T interaction was also significant. There were overall decrease after 6th year, 12th year and then after 18th year in the status of HNO_3 soluble K in soils. Chand and Swami (2000) [1] also observed similar trend that a maximum decrease in all forms of K from their initial content because of cropping with sufficient N and P without K. The depletion of K from non-exchangeable form is enhanced with higher yields and crops removals under long-term experiments and continuous cropping system.

Total K

The Status of Total K of LTFE soils was also affected significantly due to application of FYM @ 10 t ha^{-1} to groundnut and @ 15 t ha^{-1} to wheat (T_9) after 6th year, 12th year and 18th year & when pooled over years of experiment and it was significantly higher over all other treatments. Whereas at initial year it was found non-significant. The Y x T interaction was significant. There was also overall decrease in soil status of Total K after a span of 18 years. These results have been in agreement with finding of Chand and Swami (2000) [1] as explained earlier. Dinagaran *et al*. (2006) [3] noticed that the among the different forms of K, exchangeable, non-exchangeable, and total K showed significant and positive correlation with each other.

Reserve K

This fraction of potash showed significant differences at initial (1st year), after 6th, 12th year, 18th year and when pooled over years. After 6th, 12th, 18th year and when pooled over years, the significantly highest values were recorded in plot which comprised with application of FYM @ 10 t ha^{-1} to groundnut and @ 15 t ha^{-1} to wheat (T_9) i.e. 283, 237, 369 and 313 kg ha^{-1}, respectively. The Y x T interaction was found significant and there was overall decrease after 6 year as compared to initial status and slight increase after 12 year as compared to after 6 year. Rajani (2010) [11] reviewed that soils of Gujarat are drifting gradually towards negative K balance. Crops are responding to K fertilizer on irrigated and intensively cultivated area.

Depletion per cent of different forms of potassium

It is interesting to see that all the forms of potassium showed positive percent depletion in all the treatments except treatments which received FYM *i.e.* T_8 & T_9, which showed negative percent depletion. These results are also alarming us that the only inorganic fertilization can't sustain K fertility status, but addition of organic manures is necessary for sustaining K fertility in the long run. Jatav *et al.,* (2010) [6] found that WSK and Exchangeable K was decreased due to intensive cropping and K content is increasing while addition of organic FYM. Setia (2009) [14] and Sawarkar (2013) [13] conducted field experiment involving intensive cropping to study the available potassium status in soil. They observed that the potassium showed negative balance in the soil. It was decreased to initial status in all treatments.

Conclusion

It has been deducted from the Long Term Fertilizer Experiment (LTFE) in Junagadh constituting medium black calcareous soil derived from Trap basalt that the crop available forms of the potassium ascribed depletion over time irrespective of fertilizer treatments, except in treatments which received FYM along with inorganic fertilizers. Application of FYM not only sustains fertility, but also increases soil fertility status as like here in K_2O status of the LTFE soil. In treatments which received FYM, increased available-K status in LTFE soils from low category to high category.

Table 1: Status of Available-K_2O (kg ha^{-1}) in LTFE soils at initial, after 6th year, after 12th year and after 18th year.

Treat.	Available-K_2O (kg ha^{-1})				
	Initial	After 6th yr	After 12th yr	After 18th yr	Pooled
T_1	350	244	180	205	245
T_2	346	270	184	232	258
T_3	329	321	197	266	278
T_4	348	290	167	270	269
T_5	347	255	211	268	270
T_6	383	205	168	156	228
T_7	366	209	146	164	221
T_8	365	460	229	385	360
T_9	396	892	363	429	520
T_{10}	376	272	199	243	273
T_{11}	373	263	194	230	265
T_{12}	384	215	162	188	237
Mean	364	325	200	253	285
S.Em.±	19.90	33.17	13.50	21.02	10.38
C.D. @ 5%	NS	95.43	38.84	60.48	29.04
C.V. %	10.95	20.44	13.51	16.62	14.56
Y * T	S.Em.± 20.76		C.D. @ 5% 58.08		

Table 2: Status of Water soluble-K (kg ha^{-1}) in LTFE soils at initial, after 6th year, after 12th year and after 18th year.

Treat.	Water soluble-K (kg ha^{-1})				
	Initial	After 6th yr	After 12th yr	After 18th yr	Pooled
T_1	11.08	8.18	6.38	8.51	8.54
T_2	11.42	9.52	6.94	7.73	8.90
T_3	12.09	11.87	7.39	7.06	9.60
T_4	12.76	10.08	5.71	7.17	8.93
T_5	12.76	8.18	7.39	8.51	9.21
T_6	12.54	8.57	7.95	10.75	9.95
T_7	12.20	17.36	4.14	5.82	9.88
T_8	12.43	17.70	7.62	12.65	12.60
T_9	15.68	43.01	15.01	16.22	22..48
T_{10}	11.53	8.51	6.83	7.06	8.48
T_{11}	11.87	12.99	10.19	6.83	10.47
T_{12}	12.76	8.86	6.50	6.94	8.77
Mean	12.43	13.73	7.67	8.77	10.65
S.Em.±	0.61	4.19	1.46	1.66	1.18
C.D. @ 5%	1.77	12.05	4.21	4.79	3.31
C.V. %	9.91	61.00	38.15	42.64	44.49
Y * T	S.Em.± 2.37		C.D. @ 5% 6.63		

Table 3: Status of Exchangeable-K (kg ha^{-1}) in LTFE soils at initial, after 6th year, after 12th year and after 18th year.

Treat.	Exchangeable-K (kg ha^{-1})				
	Initial	After 6th yr	After 12th yr	After 18th yr	Pooled
T_1	276	192	141	160	192
T_2	272	212	144	182	203
T_3	258	251	155	211	219
T_4	273	228	131	214	211
T_5	272	200	165	211	212
T_6	301	160	129	117	177
T_7	288	154	115	129	171
T_8	287	359	179	306	283
T_9	309	688	282	339	405
T_{10}	297	214	156	192	215
T_{11}	294	202	149	182	207
T_{12}	302	167	126	147	186
Mean	291	252	156	199	223
S.Em.±	25.81	25.04	10.37	16.77	7.97
C.D. @ 5%	NS	72.05	29.85	48.24	22.29
C.V. %	17.74	19.85	13.28	16.84	14.27
Y * T	S.Em.± 15.94		C.D. @ 5% 44.58		

Table 4: Status of HNO_3 Soluble-K (kg ha^{-1}) in LTFE soils at initial, after 6th year, after 12th year and after 18th year.

Treat.	HNO_3 Soluble-K (kg ha^{-1})				
	Initial	After 6th yr	After 12th yr	After 18th yr	Pooled
T_1	517	309	273	325	356
T_2	524	330	290	365	377
T_3	473	384	297	403	389
T_4	525	351	266	403	386
T_5	559	309	309	403	395
T_6	580	270	263	281	349
T_7	627	267	237	281	353
T_8	553	577	357	573	515
T_9	687	1014	535	715	738
T_{10}	580	347	298	372	399
T_{11}	545	339	307	357	385
T_{12}	554	281	262	312	353
Mean	560	398	308	399	416
S.Em.±	29.56	29.82	19.13	21.43	10.35
C.D. @ 5%	85.13	85.80	55.04	61.65	28.96
C.V. %	10.56	15.00	12.43	10.73	9.95
Y * T	S.Em.± 20.70		C.D. @ 5% 57.91		

Table-5: Status of Total-K (kg ha^{-1}) in LTFE soils at initial, after 6th year, after 12th year and after 18th year.

Treat.	Total-K (kg ha^{-1})				
	Initial	After 6th yr	After 12th yr	After 18th yr	Pooled
T_1	5824	5558	5264	4844	5372
T_2	5824	5516	5418	5082	5460
T_3	4872	4508	4452	4116	4487
T_4	4704	4536	4578	4256	4518
T_5	5600	5418	5012	4634	5166
T_6	5488	5376	5292	4998	5288
T_7	5768	5516	5306	4956	5386
T_8	4592	4676	5138	5152	4889
T_9	5320	6104	6636	5824	5970
T_{10}	5768	5516	5026	4844	5288
T_{11}	6216	5754	5432	5040	5610
T_{12}	5600	5264	4872	4424	5040
Mean	5465	5312	5202	4848	5206
S.Em.±	538.60	165.84	194.91	227.81	85.66
C.D. @ 5%	NS	477.17	560.79	655.47	239.62
C.V. %	19.71	6.24	7.49	9.44	6.58
Y * T	S.Em.± 171.31		C.D. @ 5% 479.24		

Table 6: Status of Reserve-K (kg ha^{-1}) in LTFE soils at initial, after 6th year, after 12th year and after 18th year.

Treat.	Reserve-K (kg ha^{-1})				
	Initial	After 6th yr	After 12th yr	After 18th yr	Pooled
T_1	229	110	126	157	155
T_2	240	109	139	176	166
T_3	204	120	135	185	161
T_4	240	114	129	182	166
T_5	274	101	137	184	174
T_6	266	102	126	153	162
T_7	327	96	117	147	172
T_8	254	200	170	265	222
T_9	363	283	237	369	313
T_{10}	271	124	135	173	176
T_{11}	239	117	148	169	168
T_{12}	240	105	129	158	158
Mean	262	132	144	193	183
S.Em.±	22.62	9.27	11.05	11.72	4.65
C.D. @ 5%	65.13	26.68	31.80	33.72	13.00
C.V. %	17.26	14.08	15.36	12.13	10.17
Y * T	S.Em.± 9.29		C.D. @ 5% 26.00		

Table 7: Percent depletion of different forms of potassium after 18 groundnut-wheat sequence in LTFE soils.

Treat.	Total-K	W.S.-K	Av.-K_2O	Exch.-K	HNO_3S-K	Res.-K
T_1	16.83	23.25	41.40	42.13	37.12	31.77
T_2	12.74	32.33	33.11	33.15	30.21	26.77
T_3	15.52	41.62	19.18	18.13	14.79	8.97
T_4	9.52	43.84	22.52	21.52	23.20	24.00
T_5	17.25	33.34	22.97	22.48	27.81	32.85
T_6	8.93	14.30	59.18	61.05	51.44	42.33
T_7	14.08	52.32	55.16	55.28	55.13	55.10
T_8	-12.20	-1.75	-5.37	-6.85	-3.54	-4.49
T_9	-9.47	-3.44	-8.50	-9.88	-4.03	-1.83
T_{10}	16.02	38.80	35.46	35.33	35.74	36.07
T_{11}	18.92	42.46	38.29	38.12	34.44	29.53
T_{12}	21.00	45.64	51.14	51.37	43.68	33.90

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